Free Executive Summary

Systems and Technologies for the Treatment of Non-Stockpile Chemical Warfare Material

Committee on Review and Evaluation of the Army Non-Stockpile Chemical Materiel Disposal Program, National Research Council

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Executive Summary

The United States and other signatories of the Chemical Weapons Convention (CWC)[1] have committed to destroying all declared chemical warfare materiel (CWM) by April 29, 2007.[2] This materiel includes both stockpile materiel (all chemical agents and munitions available for use on the battlefield and stored at eight locations in the continental United States) and non-stockpile[3] materiel, a diverse category that encompasses all other CWM, which includes other chemical munitions and containers of chemical agent. Much of this non-stockpile chemical materiel (NSCM) was buried at current and former military installations in 31 states, the U.S. Virgin Islands, and the District of Columbia (U.S. Army, 1996). Only a small fraction of buried NSCM in the United States has been recovered. Virtually all NSCM that has been recovered is stored at stockpile storage sites.

The Army's baseline approach to destruction of stockpile CWM is to construct and operate state-of-the-art incinerators[4] at stockpile storage sites. However, incineration at any location, as well as transportation of agent of lethal intent across state lines, has met with strong public opposition and is subject to increasingly stringent regulatory requirements. The U.S. Army has developed or is investigating a mix of

[1]Formally known as the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction, the CWC requires the destruction of chemical weapons in the stockpile by 2007 and any non-stockpile weapons in storage at the time of the treaty ratification (1997) within 2, 5, or 10 years of the ratification date, depending on the type of chemical weapon or on the type of chemical with which an item is filled. Any chemical weapons "discovered . . . after the initial declaration of chemical weapons shall be reported, secured and destroyed in accordance with Part IV (A) of the Verification Annex" (CWC Article IV, Paragraph 9). Thus, non-stockpile CWM buried before January 1, 1997, is excluded from the treaty requirements as long as it remains buried. However, once this CWM is dug up and removed from the ground, the recovered CWM must be identified, declared under the CWC, inspected, and destroyed as soon as possible (U.S. Army, 2001a, pp. 1-3).

[2]Under the CWC, countries may apply for an extension of the deadline of up to 5 years. The United States has acknowledged that some of the stockpile destruction facilities are likely to continue to operate for several years beyond 2007. The Product Manager for Non-Stockpile Chemical Materiel (PMNSCM) has indicated to the committee that the PMNSCM intends to meet the 2007 deadline for destruction of all recovered non-stockpile materiel currently in storage.

[3]Non-stockpile chemical materiel includes buried chemical weapons, recovered chemical materiel, binary chemical weapons, former production facilities, and miscellaneous chemical materiel.

[4]The Johnston Atoll Chemical Agent Disposal System (JACADS), the initial stockpile facility, began destruction activities in 1990 and completed processing in November 2000 (U.S. Army, 2000a). There is an operating stockpile facility at Tooele, Utah, and facilities are undergoing systemization at Anniston, Alabama, and Umatilla, Oregon, and being constructed at Pine Bluff, Arkansas.

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facilities and mobile systems that employ a variety of individual treatment technologies, including:

- the Rapid Response System (RRS), a mobile system for accessing and neutralizing the contents of chemical agent identification sets (CAIS)[5]
- the Single CAIS Accessing and Neutralization System (SCANS), a system for disposing of individual CAIS vials
- the Explosive Destruction System (EDS), a mobile system for destruction of all but the largest (by size, volume of agent, or energy of dispersing charge) chemical weapons
- the Donovan blast chamber (DBC), a system developed by a private company to treat conventional munitions, but which may have application to NSCM
- the single-round container (SRC) and the multiple-round container (MRC) for moving chemical materiel to a more suitable location when necessary
- two facilities, the Munitions Assessment and Processing System (MAPS) and the Pine Bluff Non-Stockpile Facility (PBNSF), based on cutting or drill-and-drain accessing of chemical agent, followed by chemical neutralization of agent and washing of hardware, arranged in a modular style and intended to process larger numbers of non-stockpile chemical weapons at a single site
- stockpile facilities, an additional option for the destruction of NSCWM[6] created in November 1999, when Congress amended the law to allow stockpile facilities to be used to destroy non-stockpile materiel
- a tent-and-foam system for partially contained detonation of a chemical weapon judged too sensitive to move
- various technologies that may be used to treat wastes resulting from the destruction of primary NSCM, known as secondary wastes

Before these systems can be operated, however, the Army must establish their technical effectiveness and safety, obtain the necessary regulatory approvals for operation at each site where NSCM is treated, and provide opportunities for public stakeholders to be involved in the decision-making process.

Accordingly, on March 16, 2001, the PMNSCM requested that the National Research Council (NRC) review the technical and operational plans for these facilities and mobile systems, make recommendations on their interrelationships, and assess the Army's plans for obtaining regulatory approvals and for enhancing public involvement in the decision-making process.

STATEMENT OF TASK

To help optimize the technical performance, as well as the regulatory approval and public acceptance processes, of the Non-Stockpile Chemical Materiel Disposal program, the NRC will:

- Evaluate mobile destruction systems and semi-permanent[7] facilities being used or considered by the Army's Non-stockpile product manager for the treatment of non-stockpile CWM and make recommendations on the systems and facilities that could be employed by the Army and their interrelationships. This analysis will specifically include consideration of issues and opportunities associated with the Explosive Destruction System (EDS), the Rapid Response System (RRS), the Munitions Assessment and Processing System (MAPS), the Pine Bluff Non-stockpile Facility (PBNSF), alternative treatments for neat chemicals, and selected aspects of the stockpile facilities.
- Review and evaluate the issues and obstacles associated with the environmental regulatory approval process for successful employment of Non-stockpile Chemical Materiel disposal systems (mobile and semi-permanent) that the Army may encounter during its management of the Non-stockpile Program and offer recommendations that may make the regulatory approval process more efficient while reducing schedule risk.
- Recommend areas in which further detailed study efforts would be particularly useful to the Product Manager.

Subsequently, it became clear to both the PMNSCM and the committee that the planning for the PBNSF and, to a lesser extent, the MAPS was not sufficiently evolved to allow an in-depth evaluation and analysis. At this writing, the PBNSF was still in the design phase, with key treatment technologies not yet selected; MAPS, while under construction, had not yet begun systematization and operational testing. Thus, the PMNSCM directed the committee to focus on the mobile systems and individual treatment technologies that will eventually be components of MAPS and PBNSF and to comment on how these components could be used efficiently in these two facilities.

APPROACH

This report begins by describing the non-stockpile chemical weapons materiel inventory, which contains unitary munitions and accessories dating back to World War I, binary munitions, and German munitions brought to the United States after World War II (Chapter 1). The non-stockpile inventory, which encompasses a greater variety of chemical agents than the stockpile inventory, includes blister, nerve, blood, and choking agents, as well as militarized industrial

[5]CAIS were used from 1928 to 1969 to train soldiers in the detection and identification of chemical agents.

[6]Until 2000, stockpile facilities were prohibited by law from accepting non-stockpile CWM; in P.L. 106-65, however, Congress amended the law to allow non-stockpile materiel to be destroyed in stockpile facilities, provided that the states in which the stockpile facilities are located agree.

[7]The U.S. Army Corps of Engineers defines semi-permanent facilities as having a life expectancy between 5 and 25 years. For the purposes of this report, the term "facilities" is used.

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chemicals and binary agents, and its condition is highly variable (some items have severely deteriorated during decades of burial).

The committee then assesses the tools, or specific options, available to PMNSCM to safely destroy these items. These tools, which include facilities, mobile treatment systems, and individual treatment technologies, are evaluated in Chapter 2 from the standpoint of their current status, as well as technical, regulatory, and permitting (RAP) and public involvement issues. The Army has prepared assessments of the potential health and environmental impacts of its transportable treatment systems (U.S. Army, 2001a), including risks during normal operations and from accidental release of hazardous substances. Similar site-specific assessments are generally required of the Army's treatment facilities as part of the permitting process. The committee did not review the specific methodology or the regulatory assumptions used by the Army in assessing these health and environmental impacts because the overall risk assessment methodologies are of the kind typically used in U.S. regulatory and permitting programs.

In Chapter 3, the committee matches the treatment options with the materiel or munitions to be treated, identifies gaps in the program, and makes recommendations on the facilities, systems, and technologies. Chapter 4 examines RAP issues for waste management and identifies issues that, when resolved, will facilitate the RAP process in the future. Chapter 5 commends PMNSCM for its increased openness in providing information to a range of stakeholders and in developing relationships with them and notes areas that might be improved. Throughout the report, findings and recommendations follow each discussion. Appendix C evaluates the suitability of stockpile chemical disposal facilities for treating stored non-stockpile facilities. More detailed information about MAPS and PBNSF, two non-stockpile facilities, one under construction (MAPS) and one in design (PBNSF), is provided in Appendix D. Appendix E reviews the RRS and the EDS, two mobile systems for treatment of NSCWM. Appendixes F and G provide background information on regulatory and permitting issues and transportation of CWM, respectively.

Because the Army appears to be making excellent progress in destroying old production facilities, empty ton containers, and unfilled CWM delivery systems, these categories are not discussed in this report. Instead, the report covers subcategories of NSCWM whose destruction appears to pose the greatest challenges, including CAIS, recovered chemical munitions, binary CWM components, and chemical agent in bulk containers. Treatment of secondary waste streams generated in the treatment of this Non-Stockpile Chemical Warfare Materiel (NSCWM) is considered along with the treatment of primary waste.

The committee concurs with reports issued by other NRC committees (e.g., NRC, 1994) and reaffirms its own previous reports (e.g., NRC, 1999a)—namely that state-of-the-art incineration is safe and effective for the destruction of chemical weapons agent and energetics. However, the committee also recognizes that widespread opposition to incineration has led to considerable delays and additional costs. For that reason, it has worked with the Army to help evaluate alternatives to direct incineration.

The committee considered 10 categories of NSCWM that the Army currently faces or is likely to face in the future and examined the adequacy of the available treatment tools:

1. CAIS packages for in-transit gas shipment (PIGs)[8]
2. individual CAIS vials and bottles
3. small quantities of small munitions
4. chemical agent in bulk containers
5. binary chemical warfare materiel components
6. unstable explosive munitions that cannot be moved
7. secondary liquid waste streams
8. large quantities of NSCWM items currently in storage
9. large NSCWM items
10. large quantities of not-yet-recovered small munitions

The committee found that for the first seven categories, the Army has tools available or under development that should enable the destruction of NSCWM in an effective and timely way. However, significant additional investment or planning will be required to satisfactorily address the issues posed by the final three categories. Key recommendations relating to these categories appear below. The underlying discussions and findings, as well as additional findings and recommendations, appear in Chapters 1 through 5.

KEY RECOMMENDATIONS

The following findings and recommendations do not in any way diminish the committee's previous findings that state-of-the-art incineration is safe, robust, and effective (NRC, 2001a). PMNSCM has already invested considerable resources in developing treatment options to address many of the NSCWM treatment contingencies it may face. In some cases, this investment has yielded treatment systems that are ready for use; in others, treatment systems that are currently in the development pipeline should, upon completion, offer adequate capabilities.

The non-stockpile program also has available to it treatment facilities that were developed for the stockpile program, as well as commercial hazardous waste disposal facilities. To adapt these facilities for the treatment of NSCWM secondary wastes, equipment modifications or permit modifications may be required, but the technical feasibility seems

[8]PIGs are metal canisters with packing material designed to protect CAIS during transport.

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clear. The committee's findings and recommendations relating to the 10 NSCWM treatment categories are discussed further below.

Ten Treatment Categories

CAIS PIGs

Finding: The RRS is an expensive but adequate treatment system for CAIS PIGs and large numbers of loose CAIS vials and bottles. As other treatment options are also possible, this category appears to be well covered (Finding 2-7).

Individual CAIS Vials and Bottles

PMNSCM is developing the single CAIS accessing and neutralization system (SCANS) to treat individual CAIS vials and bottles recovered at remote sites. When fully developed, this system should be well suited to this task.

Recommendation: The committee recommends that PMNSCM continue to develop and optimize SCANS to increase the number of CAIS vials and bottles that can be cost-effectively treated with multiple SCANS units. If the development program results in a system that can be cost-effectively used for a large number of vials and bottles, the system should be fielded as rapidly as possible. This approach would allow reserving the RRS for treating very large numbers of CAIS and PIGs containing CAIS, which the SCANS cannot process (Recommendation 2-8).

Small Quantities of Small Munitions

PMNSCM has developed the transportable EDS[9] as the workhorse system for destruction of both explosively and nonexplosively configured munitions in the field. The EDS-1 prototype was recently deployed to Rocky Mountain Arsenal, where it successfully destroyed 10 sarin bomblets. Improved versions of the EDS-1 as well as a larger EDS-2 are currently in development. Once these developments have been completed, it appears that this category will be well covered. The EDS system appears to be sufficiently flexible that it might also be used for other NSCWM treatment categories.

Recommendation: The committee recommends that the Army continue to implement the planned improvements of the EDS that increase explosive capacity and reduce processing cycle time. The Army should consider the applicability of the EDS as modules in facilities (Recommendation 2-5).

Chemical Agent in Bulk Containers

The non-stockpile inventory includes numerous containers of chemical agents of various types and sizes that have accumulated over the years. In general, these are stored at stockpile sites. There are many treatment options available for these bulk containers; the most obvious is to use the stockpile chemical disposal facilities (CDFs), although modifications may be required and permit modifications may be difficult to obtain.

In addition to the stockpile facilities, two experimental facilities have long been used to destroy a variety of chemical agents by chemical neutralization: these are the Chemical Transfer Facility (CTF) at Aberdeen Proving Ground, Maryland, and the Chemical Agent and Munitions Destruction System (CAMDS), at Deseret Chemical Depot, Utah. Although these are R&D facilities and therefore should not be used on a routine basis to destroy NSCWM, they might be considered as an option to destroy limited numbers of non-stockpile items that contain unusual chemical fills or that have a configuration that cannot be handled by other systems.

Further treatment options for non-stockpile bulk chemicals include direct destruction in a plasma arc system (see below) or even treatment in the EDS. With all of these options available, this category is well covered.

Recommendation: While recognizing that there are significant regulatory and public acceptability issues to resolve, the committee recommends that non-stockpile chemical materiel in bulk containers located at stockpile sites and suitable for destruction in chemical stockpile disposal facilities be destroyed in those facilities (Recommendation 3-1).

Binary Chemical Warfare Materiel Components

The entire non-stockpile inventory of binary CWM components is stored in canisters and drums at Pine Bluff Arsenal, a stockpile site. Options for treatment include destruction in the Pine Bluff Chemical Disposal Facility, direct destruction in a plasma arc system, or chemical neutralization followed by oxidative posttreatment of the neutralents. The high concentration of fluorine in the binary component DF raises concerns about corrosion in some treatment systems.

Recommendation: Additional testing of plasma arc technology should be done to ensure that proposed plasma arc

[9]The EDS was originally developed to destroy non-stockpile items that were deemed too unstable for transport or long-term storage; however, it can also be used to treat limited numbers of stable chemical munitions, with or without explosive components.

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systems are capable of meeting requirements of the Environmental Protection Agency (EPA) and state requirements (Recommendation 2-10).

Recommendation: Ideally, the binary precursors methylphosphonic difluoride (DF) and ethyl-2-diisopropylaminoethyl methylphosphonite (QL) stored at Pine Bluff Arsenal should be destroyed directly, either by burning in the Pine Bluff Chemical Destruction Facility incinerator or by plasma arc treatment. If these facilities cannot handle the fluorine-rich DF destruction products, the committee recommends that on-site neutralization followed by oxidative post-treatment of the neutralents be developed. The easiest post-treatment may be shipment to a commercial incinerator capable of dealing with high levels of fluorine (Recommendation 3-2).

Unstable Explosive Munitions That Cannot Be Moved

Open burning/open detonation (OB/OD) has been the traditional method of disposing of unstable munitions, including chemical munitions, but OB/OD is no longer considered acceptable for NSCWM by regulators except in emergencies. The Army has been exploring an alternative to OB/OD called the tent-and-foam system, which provides for partially contained detonation of unstable munitions.

Recommendation: The Army should complete the development and testing of the tent-and-foam system for controlling on-site detonation of unstable munitions (Recommendation 3-3).

Secondary Liquid Waste Streams

Treatment systems such as the RRS and EDS that rely on chemical neutralization of agents produce secondary liquid waste streams of two types:

- neutralent waste streams consisting largely of organic solvents and agent neutralization by-products
- aqueous waste streams, including rinsates, washes, and brine solutions

The Army's plan for destruction of these wastes involves the collection of neutralized agent (neutralent), washes, and rinsates followed by treatment on-site or shipment to a commercial or federal treatment, storage, and disposal facility (TSDF) for final disposal. Disposal of these neutralents, washes, and rinsates would generally be by incineration. However, at least some of these liquids may be suitable for destruction by other technologies, existing or yet to be demonstrated. PMNSCM has undertaken a technology test program to test a large number of alternative technologies for destruction of these secondary waste streams.

Recommendation: The PMNSCM should continue its research and development program on chemical oxidation and wet air oxidation of neutralents and rinsates (Recommendation 2-12a).

Recommendation: Consistent with the committee's earlier analyses (NRC, 2001a, 2001b), there should be no further funding for the development of biological treatments, electrochemical oxidation, gas-phase chemical reduction, solvated electron technology, and continuous SCWO technologies for the treatment of neutralents and rinsates. PMNSCM should monitor progress in technologies being developed under the Assembled Chemical Weapons Assessment (ACWA) program but should evaluate ACWA technologies for the treatment of non-stockpile neutralents and rinsates only if no additional investment is required (Recommendation 2-12b).

In the following areas, the committee judges the treatment options that are available or in the pipeline to be insufficient to permit the non-stockpile program to meet its goals. Additional investment or planning efforts are needed.

Large Quantities of NSCWM Items Currently in Storage

Some 85 percent of all recovered NSCWM in the United States is stored at Pine Bluff Arsenal. The Army has under design the Pine Bluff Non-Stockpile Facility (PBNSF) to destroy this material, with the assistance of an RRS and an EDS to treat CAIS and certain explosively configured munitions, respectively.

Recommendation: PMNSCM should develop a detailed, realistic timetable showing how the planned non-stockpile facilities at Pine Bluff Arsenal can achieve the throughput necessary to destroy the stored non-stockpile items by April 2007 and should communicate this timetable to all stakeholders (Recommendation 2-1).

Large NSCWM Items

Disposal of chemical projectiles larger than 155 mm and large (500 or 1,000 lb) bombs presents a special challenge to the non-stockpile program. Although such munitions are rarely recovered in the United States, they have been recovered as a result of U.S. activities in at least one foreign country, and it is likely they will be found on U.S. soil in the future.

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Recommendation: PMNSCM should develop a strategy for treating chemical bombs and projectiles that are too large for treatment in the EDS, in the DBC (if successfully demonstrated), or in planned facilities. One option is to test the British drill-through valve (DTV) system, modify it if necessary, and prepare it for use on existing large NSCWM items and other such items that may be found in the future (Recommendation 3-4).

Large Quantities of Not-Yet-Recovered Small Munitions

Sites at which thousands of NSCWM items are believed to be buried present a special challenge to the non-stockpile program. Examples of such sites include Deseret Chemical Depot, Utah; Rocky Mountain Arsenal, Colorado; and Redstone Arsenal, Alabama. Use of one or even a few EDS units would be inefficient given their relatively low throughput capacity (currently one munition every 2 days). At present, the Army's only option for cleaning up such a site would be the construction of a facility such as MAPS or PBNSF. However, such facilities are expensive and have a large environmental footprint. A transportable treatment system with a high throughput would be highly desirable to treat this category of NSCWM.

Recommendation: The non-stockpile program should continue to monitor the Belgian tests of the DBC. If the results are encouraging and it appears that the DBC can be permitted in the United States, it should be considered for use at sites where prompt disposal of large numbers of munitions is required (Recommendation 2-9).

Regulatory Approval and Permitting

Historically, establishing regulatory approval and permitting (RAP) requirements for new systems and technologies has been shown to be a resource-intensive and time-consuming process. Obtaining regulatory approvals is likely to be a critical factor in meeting the treaty deadlines for the destruction of NSCWM. Communication and cooperation with regulators (particularly state regulators), combined with an effective public involvement program, are essential for obtaining regulatory approvals in a timely manner. The committee urges the Army and states to enhance the existing cooperative efforts to define appropriate regulatory requirements for the technologies.

Communicate with Regulators

Recommendation: The Army should establish a pre-permitting process to resolve RAP issues involving the Army, regulators, and the public for both mobile systems and non-stockpile treatment facilities. In addition, the Army should develop guidance on RAP for management of NSCWM. A guidance that is jointly issued by the Army and regulators, with input from the public, should be considered, and the committee recommends that it be of national scope (Recommendation 4-2).

Recommendation: The Army should examine funding provided to the states as part of existing cooperative agreements to ensure that they are sufficient to evaluate new or innovative NSCWM treatment technologies within a time frame consistent with CWC deadlines (Recommendation 4-5).

Recommendation: The Army and the states should continue to work together to achieve mutually acceptable regulations that define appropriate treatment for chemical agents and associated wastes. While state-specific treatment standards can be established, the committee recommends standards that are national in scope (Recommendation 4-6).

Develop Solid Working Relations

Recommendation: The Army should work with state regulators to tailor RAP mechanisms to the magnitude of the NSCWM recovery and treatment operations. For facilities, initial operations should be conducted under expedited RAP mechanisms (e.g., a Research, Development, and Demonstration permit); traditional Resource Conservation and Recovery Act (RCRA) permits, if necessary, should be employed after operations become routine. When mobile treatment systems or technologies are employed, and particularly for small or even moderate quantities of newly discovered NSCWM, expedited (non-RCRA permit) regulatory approval mechanisms under RCRA or the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) should be used, as appropriate (Recommendation 4-1).

Recommendation: RAP for all of the Army's chemical agent programs, including the non-stockpile program, should be seamless and transparent to the regulator and the public, who should "see" only one Army across all chemical agent programs at a specific location or operation. An installation-specific (or in the case of off-site NSCWM finds, operation-specific) core Army RAP team should be established for all chemical agent operations, including treatment of NSCWM. Installation or operation representatives should lead the RAP team at each location. The team should be directed by a central Army organization encompassing all chemical agent operations that require RAP so as to promote communication, continuity, and consistency among them. This organization should have the authority to establish RAP policy for all chemical agent operations nationwide (Recommendation 4-4).

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Avoid Unnecessary Conservatism

Recommendation: The Army should reverse its classification of CAIS as recovered chemical warfare materiel (RCWM), thus avoiding additional time and cost for their destruction (Recommendation 4-3).

Recommendation: In states where secondary waste streams are regulated as acutely hazardous, the Army should work with state regulators to remove the designation "acutely hazardous." For neutralents, the Army should work with state regulators to establish de minimis concentrations for the agents in waste streams, to be incorporated into the listing regulations, whereby the waste would no longer be considered as being associated with the parent agent waste. Further, the Army and the states should consider whether rinsates and cleaning solutions and residuals from the treatment of neutralent should be classified as hazardous waste at all (Recommendation 4-7).

Recommendation: Given the similarities between NSCWM secondary wastes and industrial hazardous wastes, the committee recommends that no additional prohibitions be placed on the off-site transportation of secondary wastes (Recommendation 4-8).

Public Involvement

As noted in the committee's three previous reports (NRC, 1999a, 2001a, 2001b), it is necessary and desirable that the Army proactively seek public involvement in policy decisions that once were considered to require only scientific judgment.

Recommendation: As with RAP activities, public involvement should appear seamless across Army programs and transparent to local and national stakeholders. The committee recommends that the Army establish central direction to ensure coordination of program and installation missions and to promote continuity and consistency in public involvement programs across installations and between program and installation staff (Recommendation 5-1).

Recommendation: The committee recommends that the Army expand its public affairs program to include involvement as well as outreach activities.[10] Specifically, for the Army to gain from lessons documented in studies of the stockpile program, the committee recommends as follows:

- The Army should direct installations to implement, in coordination with program staff, a strategy that includes development of public involvement mechanisms. Such mechanisms must be fully integrated with project schedules so that the public has a genuine opportunity to provide input to project decisions. Their goal must be to engage both the local public and other stakeholders in discussing and evaluating the various technologies being considered and to provide a continuing means of involving them in future planning efforts and project decisions.
- The Army should conduct public involvement training for program and installation personnel, including commanders, public relations, and program technical staff. Such training must be more extensive than a one-day training course in risk communication and must be conducted very early in the program. The training should be provided on a continuing basis to ensure adequate preparation of newly assigned personnel.
- NSCMP should consider how the program could more effectively use existing mechanisms, such as the Core Group, to include and engage citizens at the local, site-specific level as well as at the national level in identifying specific concerns and actively contributing to consideration of the tradeoffs inherent in program decisions (Recommendation 5-2).

[10]These components are generally consistent with the threefold division of public affairs provided in a letter report from the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program. The components were public relations (provision of written information materials), outreach (opening channels of communication to the public so that their values, concerns, and needs can be heard), and involvement (development of a formal process that gives stakeholders an opportunity to provide input to decisions without surrendering the agency's legal mandate to make those decisions) (NRC, 2000a).

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Systems and Technologies for the Treatment of Non-Stockpile Chemical Warfare Materiel

Committee on Review and Evaluation of the Army
Non-Stockpile Chemical Materiel Disposal Program

Board on Army Science and Technology

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Systems and Technologies for the Treatment of Non-Stockpile Chemical Warfare Material
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Preface

The Committee on Review and Evaluation of the Army Non-Stockpile Chemical Materiel Disposal Program (see Appendix A for biographies of committee members) was appointed by the National Research Council (NRC) to conduct studies on technical aspects of the U.S. Army Non-Stockpile Chemical Materiel Disposal Program. During its first year, the committee evaluated the Army's plans to dispose of chemical agent identification sets (CAIS)—test kits used for soldier training (NRC, 1999b). During the second year, the committee recommended nonincineration technologies that might be used for the posttreatment of neutralization wastes from Army non-stockpile materiel disposal systems (NRC, 2001a). During the third year, the Army asked the committee to supplement its report on neutralent wastes to include wastes produced by the Army's newest mobile system, the explosive destruction system (EDS) (NRC, 2001e). During this fourth year the committee has assessed the operational concepts for the mobile and semi-permanent facilities being developed by the product manager.

At its meetings, the committee was given a number of briefings (see Appendix B), and between meetings it held deliberations. The committee is grateful to the many individuals who provided technical information and insights during these briefings, particularly Lt. Col. Christopher Ross, Product Manager for Non-Stockpile Chemical Materiel, and his staff. This information provided a sound foundation for the committee's deliberations.

This study was conducted under the auspices of the NRC's Board on Army Science and Technology. The committee acknowledges the continued superb support of the director, Bruce A. Braun, as well as of NRC staff and committee members, who all worked diligently on a demanding schedule to produce this report.

John B. Carberry, *Chair*
Committee on Review and Evaluation
of the Army Non-Stockpile Chemical
Materiel Disposal Program

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Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Elisabeth M. Drake, Massachusetts Institute of Technology (retired)
Gene Dyer, consultant
F. Wayne Jennings, consultant
Herbert J. Kouts, Defense Nuclear Facilities Safety Board (retired)
Richard Magee, Carmagan Engineering
James Michael, Environmental Protection Agency
Alvin Mushkatel, Arizona State University, and
William Tumas, Los Alamos National Laboratory

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by John C. Bailar III, Professor Emeritus, University of Chicago. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Tables and Figures

TABLES

FIGURES

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Acronyms and Abbreviations

ABCDF	Aberdeen Chemical Agent Disposal Facility
ACW	assembled chemical weapons
ACWA	Assembled Chemical Weapons Assessment (Program)
ANAD	Anniston Army Depot
ANCDF	Anniston Chemical Disposal Facility
APG	Aberdeen Proving Ground
ATAP	Alternative Technology Approach Program
BGAD	Bluegrass Army Depot
BGCDF	Bluegrass Chemical Disposal Facility
CAC	Citizens' Advisory Commission
CAIS	chemical agent identification set(s)
CAMDS	Chemical Agent Munitions Disposal System
CDF	chemical disposal facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CG	phosgene
CHATS	Chemical Agent Transfer System
CK	cyanogen chloride
CN	chloroacetophenone
CSDP	Chemical Stockpile Disposal Program
CTF	Chemical Transfer Facility
CWC	Chemical Weapons Convention
CWM	chemical warfare materiel
CWWG	Chemical Weapons Working Group
D&D	drill and drain
DBC	Donovan blast chamber
DCD	Deseret Chemical Depot
DCDMH	dichlorodimethylhydantoin
DF	a binary precursor (methylphosphonic difluoride)
DM	adamsite
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPG	Dugway Proving Ground
DRE	destruction and removal efficiency
DSHW	Division of Solid and Hazardous Waste (Utah)
DTV	drill-through valve
ECC	explosive containment chamber
EDS	explosive destruction system
EIS	environmental impact statement
EPA	Environmental Protection Agency
FOTW	federally owned treatment works
FUDS	formerly used defense site
GA	tabun (nerve agent)
GB	sarin (a nerve agent)
GD	soman
H	sulfur mustard
H-$CHCl_3$	sulfur mustard in chloroform solution
HD	sulfur mustard (distilled)
HHS	Department of Health and Human Services
HL	mustard-lewisite mixture
HN-1	nitrogen mustard 1
HN-3	nitrogen mustard 3
HS	sulfur mustard
HT	mustard agent T mixture
HWIR	hazardous waste identification rule
IMPA	isopropyl methylphosphonic acid
IRP	Installation Restoration Program
JACADS	Johnston Atoll Chemical Agent Disposal System

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L	lewisite
L-$CHCl_3$	lewisite in chloroform solution
LDR	Land Disposal Restriction
MAPS	Munitions Assessment and Processing System
MDM	multipurpose demilitarization machine
MEA	monoethanolamine
MPA	methylphosphonic acid
MPF	metal parts furnace
MRC	multiple-round container
NPL	National Priorities List
NRC	National Research Council
NS	non-stockpile
NSCM	Non-Stockpile Chemical Materiel
NSCMP	Non-Stockpile Chemical Materiel Product
NSCWCC	Non-Stockpile Chemical Weapons Citizens' Coalition
NSCWM	Non-Stockpile Chemical Warfare Materiel
OB/OD	open burning/open detonation
OPA	binary component (isopropyl alcohol with amine)
OPCW	Organization for the Prohibition of Chemical Weapons
PBA	Pine Bluff Arsenal
PBCDF	Pine Bluff Chemical Disposal Facility
PBNSF	Pine Bluff Non-Stockpile Facility
PCD	Pueblo Chemical Depot
PIG	package in-transit gas shipment
PMCD	Program Manager for Chemical Demilitarization
PMNSCM	Product Manager for Non-Stockpile Chemical Materiel
POTW	publicly owned treatment works
PPM	parts per million
PS	chloropicrin
PS-$CHCl_3$	chloropicrin in chloroform solution
PUCDF	Pueblo Chemical Disposal Facility
QL	binary agent precursor (ethyl-2-diisopropylaminoethyl methylphosphonite)
RAB	Restoration Advisory Board
RAP	regulatory approval and permitting
RCRA	Resource Conservation and Recovery Act
RCWM	recovered chemical warfare materiel
R&D	research and development
RDX	cyclotrimethylenetrinitramine
RMA	Rocky Mountain Arsenal
RRS	Rapid Response System
SBCCOM	Soldier and Biological Chemical Command
SCANS	Single CAIS Accessing and Neutralization System
SCWO	supercritical water oxidation
SRC	single-round container
TNT	trinitrotoluene
TOCDF	Tooele Chemical Agent Disposal Facility
TSDF	treatment, storage, and disposal facility
USACE	U.S. Army Corps of Engineers
UCAR	Utah Chemical Agent Rule
UV	ultraviolet
VX	a nerve agent
WAO	wet-air oxidation
WHEAT	water hydrolysis of explosives and agent technologies
WIPT	working integrated process team
3X	level of decontamination (suitable for transport or further processing)
5X	level of decontamination (suitable for commercial release)

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